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㊽発光ダイオード素子にけい光体を塗布する方法

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㊼特許請求の範囲

1　赤外発光性の発光ダイオード素子の発光部分を有する端面に赤外線の励起によつて可視光を発するけい光体粉末と、前記けい光体粉末の1～10%の樹脂を溶剤によつて希釈してなる分散媒を付着させ、次いで上記発光ダイオード素子を倒立保持し、その下端に懸垂して付着している上記分散媒中でけい光半粉末が下方に集中沈降した状態のままで、分散媒を乾燥させる事を特徴とする、赤外発光性の発光ダイオード素子に赤外線の励起によつて可視光を発するけい光体を塗布する方法。

発明の詳細な説明

本発明は、発光ダイオード素子にけい光体粉末を塗布する方法に関する。

最近、砒化ガリウム発光ダイオードなどに、不純物などを入れ近赤外域に発光を持つ様にした、赤外発光性の発光ダイオード(以下単に発光ダイオードという)の通常ウエハーと呼ばれる発光部分に、赤外線の励起によつて可視光を発するけい光体(以下単にけい光体という)例えばYF_3:Yb・Er、LaF_3:Yb・Er等を塗布し可視発光性の発光素子を得る事が試みられている。

この種のけい光体は、赤外強度の累乗に比例して可視発光強度が増すため励起密度を高める必要がある事、可視発光を取り出すためには、けい光体層の厚さが問題になる事、それ自体が特殊なけい光体で極めて高価な事、そして発光ダイオードの発光部分が極めて薄く、大きさも一辺が数百ミクロンの方形で極めて小さい事などから、少量のけい光体を発光部分に集中し接近させて塗布する必要がある。

この様に、小さな表面上に塗布するという事は、高輝度でバラツキの少いけい光体塗膜を得る事が必要であるに拘わらず極めて困難な現状にある。

従来、この様な小さな表面に塗布する方法としては、刷毛塗りあるいは沈降法などの方法がとられている。しかし、これらの方法により小さい表面上に発光部分からの赤外線の全反射をさけて効率良く可視発光を取り出すための、均一なドーム状塗膜を再現性よく得る事は非常に困難であつた。

本発明はこれらの難点を解決した画期的な塗布方法である。本発明によれば、液滴及び粉体の一般的な物理的特性を利用する事により、小さな素子面上に均一なドーム状のけい光体塗膜を再現性良く形成しうる。

本発明の塗布方法は発光ダイオード素子の発光部分を有する端面に、けい光体粉末および分散媒を付着させ、次いで上記発光部分が下方に位置する様に上記発光ダイオード素子を倒立して保持しその下端に懸垂して付着している上記分散媒の液滴中で上記けい光体粉末が下方に集中して沈降した状態で、上記分散媒を乾燥させる事を特徴とするものである。

以下、図面により本発明の方法を更に具体的に示す。

第1図aに示す様に、水平に保たれたダイオード1の発光部分を有する端面の上にけい光体2を直接所要量乗せる(b)。

その上にバインダーとなる樹脂等を、溶剤に溶解した分散媒3を、注射器等の細いノズルから適当量滴下する。

滴下された液滴は、自由表面に作用する表面張力により発光端面上に置かれたけい光体等の粉体を包含した状態でドーム状（以下ドームと略称）となる（c参照）。

この様な状態(c)のものを得る手順として上記の外に先に分散媒を滴下しドームを形成している中にけい光体を投下する方法、およびけい光体と分散媒を混合して同時に素速く滴下する方法なども勿論、本発明に包含される。

いずれの方法によるにしろ重要なことは、分散媒がけい光体粉末を包含してドームを形成することである。

以上のようにして(c)を得たら、次にこれを自由表面が下向きになるように半回転させる。すなわち発光ダイオードを倒立して発光部分を有する端面が下向きで水平になるように保持する。かくてけい光体の比重が分散媒より充分大きいため、ドーム状に懸垂した分散媒の液滴内に包含されたけい光体等の粉体は、ドーム液滴内を沈降し、ドームの頂点附近に集まろうとする。かくて液滴内の粉体分布は(d)の如くになる。次いでそのまゝ（自由表面を下向きで、水平に保持した状態）これを適当な温度で乾燥する。

適温乾燥により稀釈溶剤は気化していき、けい光体粉末は樹脂と共に徐々にダイオード発光端面を中心とする附近にドーム状になつて付着する（e参照）。

以上のような方法によつて得られたけい光体の付着したダイオードは通電により発する赤外線を効率良く可視光に変換し、極めて高輝度の緑色発光を呈す。

ダイオードの赤外光を効率良く可視光に変換し、それを外部にとり出すためには前述の如くダイオードにのせるけい光体量、樹脂と溶剤からなる分散媒の組成等により決定する。けいこう体層、密着性、形状等が重要な要素となる。

これらの関係を解明するため、さらに本発明を詳述する。

可視光を最も効率良く取り出すには、ダイオードに付着したけい光体層に最適厚さが存在する。第6図にけい光体層の厚みと、外部に取り出された発光（相対）輝度の関係の一例を示した。

この例はバインダーを用いない場合の例であるが、0.2～0.6mmの範囲で最高輝度が得られるという目安が得られた。次にいくつかの例示樹脂をバインダーとして用いてダイオードにのせるけい光体量を変化させた場合のけい光体量と取り出された輝度の関係を第2図に示した。またけい光体量と測定されたけい光体層厚の関係を第3図に示した。

これら両図より可視光を最も効率よく取り出す、つまり最大輝度を得るためのけい光体の所要量は各種樹脂の使用に依存せず2から6mg位であり、けい光体層厚で0.1から0.5mmの範囲であることが明らかになつた。特に2から4mgの範囲において最も明らかになつた。特に2から4mgの範囲において最も再現性良く良好な結果を得る。

バインダーとなる樹脂は

① 可視光を取り出すため透明で耐候性の良い事、

② 発光ダイオードの屈折率が高いので、ドーム状にした時全反射しないようにするため、屈折率がなるべく大きい事、

③ 加熱乾燥するため熱硬化型で金属に対する密着力を有する事、

④ 発光端面や導線部を腐蝕しない事など

を満足させる樹脂が適当である。上記諸条件に合うものとしては、エポキシ樹脂、アクリル樹脂、シリコーン樹脂、ポリスチレンやポリビニールアルコールなどがある。しかし特に良好なものは、前三者である。

樹脂の所要量は現在市販のものでも固型もしくは溶媒に溶かしたものなどがあるため特定はしがたいが、とにかくけい光体粒子相互を結合させ、発光端面附近に付着するに要する最少の量であることが望ましく、いずれも、けい光体量に対する固型樹脂分の重量比にして約1～10％が最適であることが判明した。

樹脂の選択に次いで重要なことは、分散媒を構成する溶剤の種類及びその量の問題である。とにかくけい光体が分散媒中を自由に動くこと及び余分な樹脂分を少なくするため適当な稀釈溶媒を入れることが必要である。

この溶剤は乾燥により気化するため樹脂の様な特性は必要としない。例えばトルエン、アセトン、キシレンなどが挙げられるが色々な樹脂に合せて、

乾燥時徐々に気化する必要が有る為、比較的沸点の高い物を主成分とすることが望ましい。又前記樹脂を良く溶かすという条件も考慮に入れると、トルエンやキシレンが最適である。その所要量は第4図と第5図に示す如く、市販の樹脂溶液（樹脂固型分50％前後）を使用した場合、いずれも重量比で10倍から30倍の範囲が良く、輝度及びけい光体層の形状等の再現性及び取り扱い易さの点から特に20倍附近が最適である。

本発明に於て乾燥温度は、溶剤が徐々に気化し後で樹脂が固まる様に2段階に選ぶのが良く最初の乾燥段階は室温から100℃以下特に70℃附近、後の樹脂硬化はそれぞれ樹脂で当然異るが200℃附近が好ましい。この様にして得られた本発明の発光素子は、可視発光輝度に於いて第2図や第4図に示す如く、高輝度が再現性良く得られる。これは厚みにおいても第6図に示された最適厚附近のけい光体塗膜が第3図や第5図の如く再現性良く得る事ができることによる。そしてその輝度は、刷毛塗り、沈降法など公知の塗布方法に比較し1.5〜2倍も明るくなる。

従来公知の塗布方法では、本発明の様に微少部分に収率よくおよび再現性よく高価なけい光体を塗布することは全く不可能に近い。

本発明の塗布方法は、けい光体と他の粉末を混合して塗布する場合も適用範囲として含むものである。また元々可視発光を出す発光ダイオードの発光端面上に光を拡散する為に光拡散用の粉末を塗布する場合にもその技術を応用することができる。

さらに本発明の塗布方法によりけい光体を塗布した上に、けい光体を含まない樹脂溶液を塗布すると、機械的強度の補強と光の利用率の向上のために一層効果的である。

以下実施例により本発明を詳述する。

実施例　1

シリコン樹脂（トーレシリコーン製SH−805（固型分50％溶剤キシレン））	1gr
トルエン	10gr
けい光体	4mg

第1図に示すが如く、上記けい光体をダイオードの発光端面上に乗せ、上記樹脂及び溶剤の混合

物を注射器の様な細いノズルから数百mg滴下して、ドームを作り、次いで半回転して逆水平にし、60℃位で、1時間程乾燥後、250℃位で4時間乾燥する。

かくて第3図および第4図に示される様な最適な厚みと高輝度を得ることができた。

実施例　2

アクリル樹脂（三菱レーヨン製ダイヤナール1034（固型分30％溶剤キシレン））	1gr
トルエン	15gr
けい光体	3mg

第1図に示すが如く上記けい光体を発光ダイオードの発光端面上に乗せ、上記樹脂及び溶剤の混合物を注射器等の細いノズルから数百mg滴下して、ドームを作り、次いで半回転させ、逆水平にし、60℃位で1時間程乾燥し、更に100℃位で4時間乾燥する事により第3図および第4図に示す様な最適な厚みと高輝度を得た。

実施例　3

エポキシ樹脂（シエル化学製エピコート1004（固型分30％））	1gr
トルエン	10gr
けい光体	3mg

第1図に示す如く、上記けい光体を発光ダイオードの発光端面上に乗せ上記樹脂及び溶剤の混合物を注射器のノズルから数百mg滴下してドームを作り、半回転させ、逆水平にし、60℃位で1時間程乾燥した後、200℃位で2時間乾燥。

かくして第3図および第4図に示す様な最適な厚みと高輝度を得た。

実施例　4

シリコン樹脂（トーレシリコーン製SH−808（固型分50％溶剤キシレン））	1gr
キシレン	15gr
けい光体	4mg

上記樹脂と溶剤の混合物を注射器で発光ダイオード発光端面上に数百mgに滴下しドームを作り、そのドームの頂点附近にけい光体を注意深く投入し、端面上に沈降させた後、半回転させ、逆水平

にし、60℃位で1時間更に250℃位で2時間乾燥した。かくて、第3図及び第4図に示されるのと同様な良好な厚みと高輝度が得られた。

図面の簡単な説明

第1図は本発明による塗布方法を簡単にその順序に従い示したものである。第2図は本発明の塗布方法を適用して、赤外発光ダイオードに赤外可視変換けい光体を塗布した場合の分散媒を一定としたけい光体重量と可視光輝度の関係を示すものである。第3図は第2図に関連する物の、けい光体重量と塗布厚の関係である。第4図は本発明の塗布方法を適用して、赤外発光ダイオードに赤外可視変換けい光体を塗布した場合のけい光体重量を一定とした分散媒中の樹脂溶液（樹脂固型分を約50%溶剤に溶かした市販の物）対稀釈溶剤比と可視発光輝度の関係を示すものである。第5図は第4図の樹脂溶液対稀釈溶剤比と塗布厚の関係を示すものである。第6図はけい光体の厚みと輝度の関係を示すものである。

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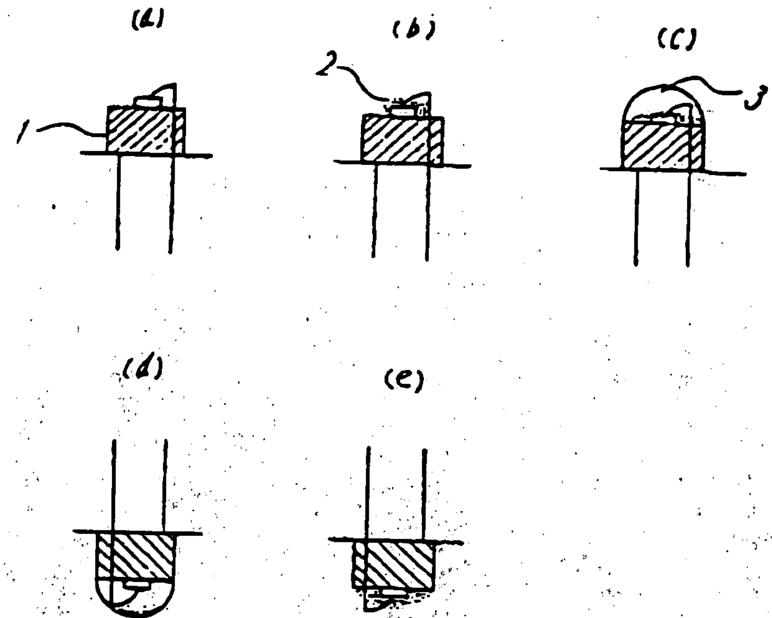
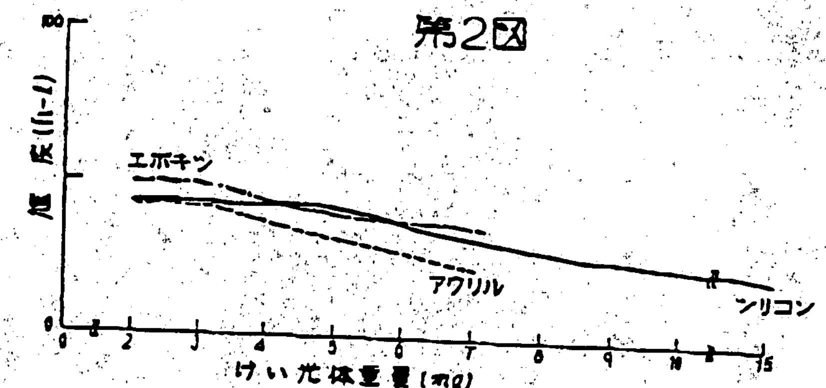
Journal of Electrochemical Society 116 〔12〕 P.P.1718〜1722'69−12

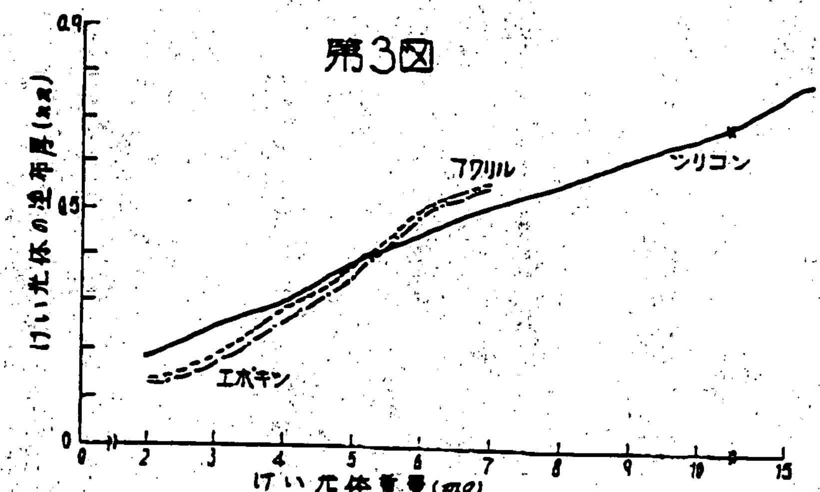
第1図



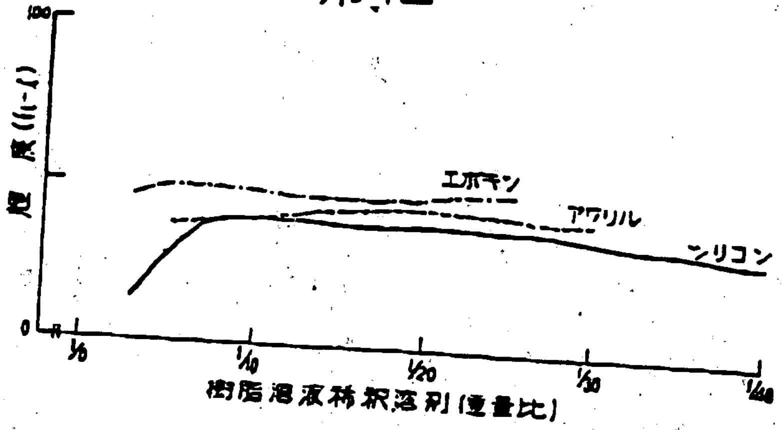
第2図



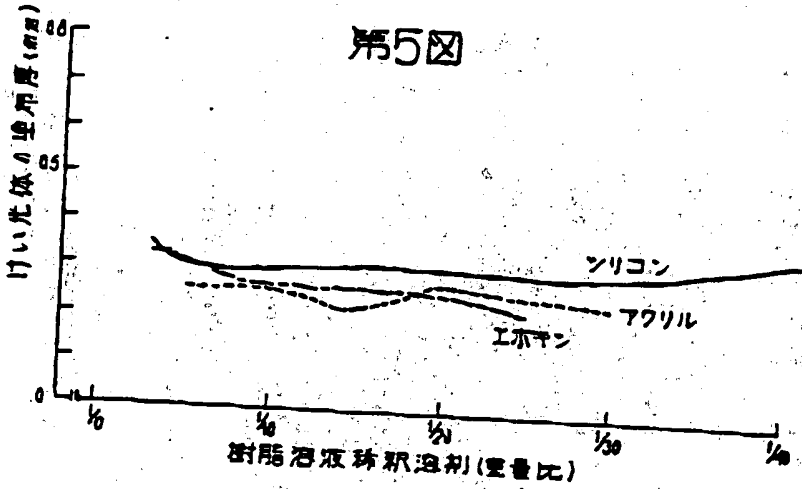
第3図



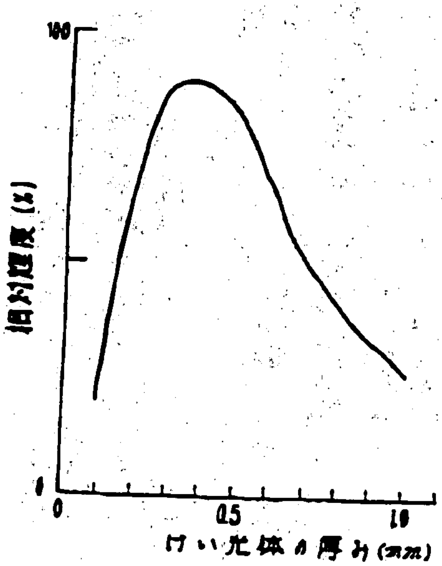
第4図


100
0
エポキシ
アクリル
シリコン
1/10
1/20
1/30
1/40
樹脂溶液稀釈溶剤(重量比)

第5図


0.5
0
シリコン
アクリル
エポキシ
1/10
1/20
1/30
1/40
樹脂溶液稀釈溶剤(重量比)

第6図


100
0
0
0.5
1.0
けい光体の厚み(mm)

BAD

JP 52-40959

(54) Method for applying a luminous substance on a light-emitting diode element
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(43) Publication date: April 8, 1974
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(57) Claim

1. Method for applying a luminous substance that emits visible light when stimulated by infrared radiation on an infrared light-emitting diode element, characterized in that
a luminous substance powder that emits visible light when stimulated by infrared radiation and a dispersion comprising a resin [in an amount] of 1 to 10% based on [the amount of] said luminous substance powder and diluted in a solvent are adhered to that end face of an infrared light-emitting diode element having a light-emitting portion,
then said light-emitting diode element is held in an upside down position, and said dispersion is dried in the condition where said luminous substance powder concentrates in said dispersion suspended from the bottom end of said light-emitting diode element, by sedimenting in a downward direction.

Detailed Explanation of the Invention

The present invention relates to a method for applying a luminous substance powder on a light-emitting diode element.

Recently it is being attempted to obtain light-emitting elements capable of emitting visible light by applying a luminous substance that emits visible light when stimulated by IR radiation (in the following simply referred to as "luminous substance"), such as YF_3: Yb · Er or LaF_3: Yb · Er, to a light-emitting portion of an IR light emitting diode (in the following simply referred to as "LED"), generally referred to as a wafer, that is caused to have a light emission in the near infrared range by introducing impurities etc. into a gallium arsenide type light-emitting diode or the like.

With this kind of luminous substance, the luminous intensity of visible light increases in proportion to a power of the infrared luminous intensity, so that it is necessary to increase the stimulation density; in order to obtain an output of visible light, the thickness of the luminous substance layer is a problem, which in itself is a specialized luminous substance and extremely costly; moreover the light-emitting portion of the LED is extremely thin and furthermore extremely small, having a square shape with a side length of several hundred microns; it is accordingly necessary to coat the light-emitting portion by applying a small amount of luminous substance on it in a concentrated manner.

Therefore, although it is necessary to obtain a luminous substance film with high luminance and little scattering of luminance, coating application on a small surface is thus extremely difficult.

Conventionally, brush application or sedimentation methods have been utilized for the coating application on such small surfaces. However by such methods it was very difficult to produce with good reproducibility the homogeneous dome-shaped coating film on a small surface for a highly efficient output of visible light while avoiding full reflection of the infrared radiation from the light-emitting portion.

The present invention is an innovativ application method that solves the mentioned problems. In accordance with the present invention, uniformly dome-shaped luminous substance coating films are formed on small element surfaces with good reproducibility by making use of the general physical properties of the droplet of liquid and of the powder.

The application method according to the invention is characterized in that a luminous substance powder and a dispersion are adhered to that end face of an infrared light-emitting diode element having a light-emitting portion, then the light-emitting diode element is turned upside down so that the light-emitting portion is positioned at the bottom, and the dispersion is dried in the condition where the luminous substance powder concentrates in the liquid drop of dispersion suspended from the bottom end of the light-emitting diode element by sedimenting in a downward direction.

In the following, the method of the present invention is explained more specifically by referring to the figures.

Onto the end face of a diode 1 having the light-emitting portion, held horizontally in accordance with the representation of Fig. 1a, a required amount of luminous substance 2 is placed directly (b).

An appropriate amount of dispersion 3 of a resin or the like as a binder, dissolved in solvent, is placed on top of this as a droplet through the narrow nozzle of a syringe or the like.

The applied drop of liquid, while enclosing the powder such as the luminous substance placed on the light-emitting end face, assumes a dome-shape (hereinafter referred to as "dome") due to the surface tension acting on its free surface (cf. (c)).

As a measure for obtaining this condition (c) apart from the above mentioned one, there are, of course, other methods, such as to introduce the luminous substance into a dome formed by applying a drop of dispersion in advance, or

to mix the luminous substance and the dispersion and rapidly apply them jointly as a drop, however these methods ar encompassed by the present invention.

Independently of the method used, the important point is that the dispersion encloses the luminous substance powder and forms a dome.

Once the above mentioned state (c) has been obtained, the whole is rotated half a turn to make the free surface face downward. I.e., the LED is turned upside down and held horizontal, with the end face having the light-emitting portion facing downward. As the luminous substance has a far greater specific weight than the dispersion, a powder of luminous substance etc. that is enclosed in the droplet of dispersion suspended in a dome shape will be sedimented inside the dome-shaped liquid droplet and gather near the apex of the dome. The distribution of the powder inside the liquid droplet will thus resemble the one in (d). Subsequently the whole is dried at a suitable temperature while in this condition (i.e., held horizontal, with the free surface facing downward).

By drying at a suitable temperature, the diluting solvent gradually evaporates so that the luminous substance powder together with the resin adheres in a dome shape centered on the light-emitting end face of the diode (cf. (e)).

The diode obtained in accordance with the above method and having a luminous substance adhered to it converts the infrared radiation emitted as a result of current passing through it into visible radiation, to thereby develop a green light of very high luminance.

Whether the infrared light of the diode is converted into visible light at a good efficiency and extracted to the outside, is determined in accordance with the above description by the amount of luminous substance placed on the diode, the composition of the dispersion comprising resin and solvent, etc.. Luminous substance layer, adhesion capability, shape etc. are importance factors.

The invention shall now be described further so as to elucidate the relevance o these relationships.

For obtaining maximum effici nt output of visible light, there exists an optimum thickness of the luminous substanc layer adhered to the diode. Fig. 6 shows an example for the relationship between the luminous substance layer thickness and the possible output of (relative) emission intensity.

In this example no binder was employed, but it provided the indication that a maximum luminance is obtained in a range of 0.2 - 0.6 mm. Fig. 2 shows the relationship between the luminous substance quantity and the possible luminous output while changing the amount of luminous substance applied on the diode by using several exemplary resins as a binder. Fig. 3 shows the relationship between the luminous substance quantity and the measured luminous substance layer thickness.

From the two figures it could be seen that the amount of luminous substance required for maximum efficiency output of visible light, i.e. for attaining maximum luminance, independently of the kind of resin used is about 2 - 6 mg, with a luminous substance thickness in the range of 0.1 - 0.5 mm. It also became clear that the best results with the best reproducibility were obtained in the range of 2 - 4 mg.

Suitable binders are those resins that are capable of satisfying the following demands:

① High transparency for outputting visible light, and good weathering resistance;

② a maximum possible refraction coefficient to avoid full reflection due to the high refraction coefficient of dome-shaped LEDs;

③ heat settability for drying in heat, and metal bonding capability;

④ no corrosion to light-emitting end face and lead parts.

These conditions are satisfied by epoxy resin, acrylic resin, silicone resin, polystyrene and polyvinyl alcohol, with the former three being particularly preferred.

It is not easy to determine the required amount of resin even with currently marketed resins, whether solid or in solution in a solvent; it was, however, found that in any case the minimum quantity required for binding the luminous

substance particles to each other and bonding them in the vicinity of the light-emitting end face is desirable, and that for each resin a solid amount of approx. 1 - 10% based on the weight of the luminous substance is most suitable.

Having selected a resin, there is the problem of kind and quantity of the solvent for forming the dispersion. In any case the addition of diluting solvent should be adequate for allowing the luminous substance to be freely movable in the dispersion, and reducing an excess resin content.

The solvent is evaporated by drying and thus needs not satisfy the properties demanded of the resins. Toluene, acetone, xylene may be named as examples for suitable solvents; however the solvent should furthermore include a main component having a comparatively high boiling point because it should gradually evaporate during drying in harmony with a respectively used resin. When furthermore considering the condition of well dissolving the above mentioned resins, toluene and xylene are suited best. As is shown in Figs. 4 and 5 with regard to their required quantities, when using a commercially available resin solution (solid proportion: approx. 50%) they are all preferably used in a quantity in the range of 10 - 30 times the weight of the resin, but in terms of luminance and reproducibility of the shape of the luminous substance layer as well as easy handling, 20 times the weight of the resin is suited best.

In accordance with the invention, the drying temperature is suitably selected for two stages such that at first the solvent gradually evaporates, and then the resin cures. For the first drying step the temperature preferably is from room temperature to 100°C, particularly around 70°C, and for the later curing step a temperature of approx. 200°C depending upon each respective resin is preferred. As is shown in Figs. 2 and 4 with regard to the intensity of visible light emission, the light-emitting element of the invention obtained in this way has high luminance with good reproducibility. The reason for this is that the thickness of the luminous substance coating film, as well, may be obtained near the optimum thickness, as is shown in Fig. 6, at good reproducibility, as is shown in Figs. 3 and 5. In accordance with the method of the invention, luminance is moreover 1.5 - 2 times as high as with those obtained in accordance with the known methods such as brush application, sedimentation etc. methods.

In accordance with the previously known application methods it is hardly possible to efficiently apply a costly luminous substance on a very small part with good yield and good reproducibility as in accordance with the method of the invention.

The application method of the present invention furthermore encompasses the application range of applying a luminous substance in a mixture with other powders. The technique according to the invention may also be used to apply a powder having the purpose of scattering light on the light-emitting end face of an LED that emits visible light.

Application of a resin solution without luminous substance on an applied luminous substance in accordance with the application method of the invention moreover has the effect of further improved mechanical strength and utilization factor.

In the following, the invention shall be explained in detail by way of examples.

Example 1

Silicone resin (SH-805 by Toray Silicone (50% solid in xylene as a solvent))	1 g
Toluene	10 g
Luminous substance	4 mg

As is shown in Fig. 1, the above mentioned luminous substance was placed on the light-emitting end face of a diode, and several hundred 100 mg of a mixture of the mentioned resin and solvent was deposited as a droplet through a narrow nozzle such as of a syringe, so as to form a dome; then the whole was rotated half a turn into a reverse horizontal position, dried for about 1 h at approx. 60°C, and dried further for about 4 h at approx. 250°C.

In this way, the optimum thickness and high luminance in accordance with the representation of Figs. 3 and 4 could be obtained.

Example 2

Acrylic resin (Dianal 1034 by Mitsubishi Rayon (30% solid in xylene as a solvent))	1 g
Toluene	15 g
Luminous substance	3 mg

As is shown in Fig. 1, the above mentioned luminous substance was placed on the light-emitting end face of a diode, and several hundred 100 mg of a mixture of the mentioned resin and solvent was deposited as a droplet through a narrow nozzle such as of a syringe, so as to form a dome; then the whole was rotated half a turn into a reverse horizontal position, dried for about 1 h at approx. 60°C, and dried further for about 4 h at approx. 100°C; hereby the optimum thickness and high luminance in accordance with the representation of Figs. 3 and 4 were obtained.

Example 3

Epoxy resin (Epicoat 1004 by Shell Chemical (30% solid))	1 g
Toluene	10 g
Luminous substance	3 mg

As is shown in Fig. 1, the above mentioned luminous substance was placed on the light-emitting end face of a diode, and several hundred 100 mg of a mixture of the mentioned resin and solvent was deposited as a droplet through a narrow nozzle such as of a syringe, so as to form a dome; then the whole was rotated half a turn into a reverse horizontal position, dried for about 1 h at approx. 60°C, then dried for about 2 h at approx. 200°C.

In this way, the optimum thickness and high luminance in accordance with the representation of Figs. 3 and 4 could be obtained.

Exampl 4

Silicone resin (SH-808 by Toray Silicone (50% solid in xylene as a solvent))	1 g
Xylene	15 g
Luminous substance	4 mg

The mixture of several 100 milligrams of the above mentioned resin and the above mentioned solvent was deposited on the light-emitting end face of a diode as a droplet through a syringe, so as to form a dome. After that a luminous substance was introduced by injecting it deeply near the apex of the dome and made to sediment on the end face. Then the whole was rotated half a turn into a reverse horizontal position, dried for about 1 h at approx. 60°C and further for about 2 h at approx. 250°C.

Short Explanation of the Figures

Fig. 1 is a simplified representation of the application method of the invention in the order of working. Fig. 2 shows the relationship between the luminous substance weight and the luminance of visible light with a defined dispersion for an infrared-emitting diode on which a luminous substance for converting IR into visible radiation is applied in accordance with the application method of the present invention. Fig. 3 relates to Fig. 2 and shows the relationship between the luminous substance weight and the coating thickness. Fig.4 shows the relationship between the resin solution (commercial product with approx. 50% solid resin dissolved in the solvent) / diluting solvent ratio in the dispersion and the luminance of visible radiation with a defined luminous substance weight for an infrared-emitting diode on which a luminous substance for converting IR into visible radiation is applied in accordance with the application method of the present invention. Fig. 5 shows the relationship between resin solution / diluting solvent ratio specified in Fig. 4 and coating thickness. Fig. 6 shows the relationship between thickness of the luminous substance and luminance.

(56) Cit d literature

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Fig. 1

Fig. 2
Epoxy *Acrylic* *Silicone*
(absc.) Luminous substance weight (mg)
(ord.) Luminance (fL)

Fig.3
Epoxy *Acrylic* *Silicone*
(absc.) Luminous substance weight (mg)
(ord.) Thickness of applied luminous substance (mm)

Fig. 4
Epoxy *Acrylic* *Silicone*
(absc.) Resin solution/diluting solvent (wt. ratio)
(ord.) Luminance (fL)

Fig. 5
Epoxy *Acrylic* *Silicone*
(absc.) Resin solution/diluting solvent (wt. ratio)
(ord.) Thickness of applied luminous substance (mm)

Fig. 6
(absc.) Luminous substance thickness (mm)
(ord.) Relative luminance (%)